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REPORT ON THE ILLINOIS RIVER SYSTEM. WATER QUALITY GOALS

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This special report on water quality goals for the Illinois River system was prepared in response to a request from the Public Health Service. A summary of water uses is given with a selected list of the water quality parameters whose numerical values are generally indicative of the suitability of particular waters for each use. Specific recommendations are made for coliforms, dissolved oxygen, alkyl benzene sulfonate, chlorides, and total dissolved solids. A bibliography is included.

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REPORT

ON THE

ILLINOIS RIVER SYSTEM

WATER QUALITY GOALS

January 1963

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

Division of Water Supply and Pollution Control

Great Lakes-Illinois River Basins Project

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SUMMARY

This special report, Water Quality Goals for the Illinois River System, was prepared in response to a request from the U. S. Department of Justice for water quality goals recommended by the Public Health Service.

1. Water Uses

A summary of water uses, and a selected list of the water quality parameters whose numerical values are generally indicative of the suitability of particular waters for each use.

2. Recommended Quality Goals - Upper Illinois River System

A discussion of present and expected uses of water in the Upper Illinois River System, together with recommended goals to make the water satisfactory for those uses.

The danger of generalization, in assigning numerical values to water quality parameters, is to be clearly recognized. The criteria given herein apply only to the Upper Illinois River System as described in the section entitled "RECOMMENDED QUALITY GOALS - UPPER ILLINOIS RIVER SYSTEM" and only for those water uses stated.

The following criteria are recommended for the Upper Illinois River System:

Coliforms:

Iterim Goal - Monthly geometric mean coliform density of 10,000 per 100 milliliters.

Ultimate Goal - Maximum coliform density of 5,000 per 100 milliliters on the basis of monthly geometric means, and further, the density of 5,000 coliforms per 100 milliliters should not be exceeded in more than 20% of the samples examined during any one month.

Dissolved Oxygen:

Interim Goal - Daily average not less than 3.0 milligrams per liter (mg/l)

Ultimate Goal - Not less than 5.0 mg/l

Alkyl Benzene Sulfonate (ABS):

Not more than 0.5 mg/l just below the confluence of the Des Plaines River with the Kankakee River.

Chlorides:

Not more than 100 mg/l

Total Dissolved Solids:

Not more than 500 mg/l

WATER USES

Major uses of water have been listed by Camp (1), McKee (2), and also in a manual titled "WATER QUALITY CRITERIA" (3), compiled by the California Water Pollution Control Board. By adaptation from these references, the following tabulation of the major uses of water has been established for the purpose of this special report.

1. Municipal Water Source

2. Industrial Process

3. Recreational

    a) Swimming and Water Skiing
    b) Boating, Fishing, and Hunting

4. Irrigation

5. Fish and Aquatic Life

6. Wildlife and Livestock Watering

7. Miscellaneous

    a) Hydroelectric Power
    b) Commercial Shipping
    c) Cooling
    d) Waste-Water Assimilation and Transport
    e) Esthetic Enjoyment and Property Right

The order of presentation in the foregoing list is not intended to signify priority, relative importance, or stringency of quality requirements. The relative importance of these beneficial uses for any stream, lake, or ground-water basin depends on the economy of the area and the needs of the inhabitants. Narrow limits of water quality are necessary if water is to be satisfactory for municipal source and industrial process water, certain agricultural needs, recreation, and fish and wildlife. Those uses which tend to alter water quality, such as waste disposal, return irrigation flows and drainage from erodible areas, may limit or prevent its usefulness for many purposes.

For the purposes of this report five parameters of quality have been suggested for consideration. These parameters were selected because, at the present time, they are the most significant indicators of quality that affect present day uses in the Upper Illinois River System.

These parameters are:

1. Coliform density, expressed as number per 100 milliliters

2. Dissolved Oxygen (DO), expressed as milligrams per liter (mg/l)

3. Alkyl Benzene Sulfonate (ABS), expressed as mg/l of ABS

4. Chlorides (Cl^-), expressed as mg/l of Cl^-

5. Total Dissolved Solids, expressed as mg/l

RECOMMENDED QUALITY GOALS - UPPER ILLINOIS RIVER SYSTEM

The Upper Illinois River System, for purposes of this discussion, is defined as the system of natural and man-made channels extending from the three inlet points on Lake Michigan to the confluence of the Sanitary and Ship Canal with the Des Plaines River.

The present principal uses of the Upper Illinois River System are commercial shipping, waste-water assimilation and transport (principally treated), and industrial cooling water. Of secondary significance are hydroelectric power production and recreational boating. Although the Upper Illinois River System is not used extensively for recreation at the present time, its quality has a significant influence on downstream conditions where recreational activities are prevalent. In addition to the uses noted above, the lower river is also used as a source of municipal water supply, industrial process water, and fish and wildlife habitation.

Although human contact with waters of the Upper Illinois River System is incidental to, rather than an essential feature of its present principal uses, there exists nevertheless, a definite health hazard. There are many who are attracted by the water and come in contact with it, unaware of the potential danger. For these reasons, the quality of this water has public health significance which cannot be ignored. It should be pointed out that the estetic condition of the Upper Illinois River System is also important. To this end the streams should be freed of objectionable floating material and oil, and free of objectionable orors. Further, to provide adequate protection for the various water uses, concentrations of toxic substances should not be present in sufficient concentrations as to be detrimental to these uses.

An essential step in any water quality management or pollution control program is the selection of quantitive goals to be attained. The goals selected should not only protect the uses prevalent in the Upper Illinois River System; they should protect the uses in the lower river as well. To that end, the following criteria for the Upper Illinois River System are suggested.

Coliforms

It is recommended as an ultimate goal, that the coliform density not exceed 5,000 per 100 milliliters on the basis of monthly geometric means at all points in the Upper Illinois River System, and, further, that this density of 5,000 coliforms per 100 milliliters should not be exceeded in more than 20% of the samples examined during any one month.

During the period in which the sewerage system and treatment works are being modified to meet the ultimate goal, it is recommended

that a monthly geometric mean coliform density of 10,000 per 100 milliliters be permitted at all points in the Upper Illinois River System. This modified goal is believed to be warranted due to the following special circumstances: 1) that recreational boating presently is confined primarily to temporary exposure while boats are in transit between the two more attractive recreational areas, Lake Michigan and the lower river; and 2) that the complex problem created by spillage from sewers will require many years for correction.

Dissolved Oxygen

It is recommended, as an ultimate goal, that a minimum dissolved oxygen concentration of five milligrams per liter be present at all points in the Upper Illinois River System.

The accomplishment of the ultimate goal may have to await the development of more efficient waste treatment methods (to reduce the oxygen demands entering the stream), or measures for increasing the dissolved oxygen content. In the interim, it is considered that a feasible goal is a minimum daily average of 3.0 milligrams per liter of dissolved oxygen.

Detergents

It is recommended that the maximum allowable concentration for detergents be 0.5 milligrams per liter measured as alkyl benzene sulfonate (ABS) just below the confluence of the Des Plaines River with the Kankakee River. This monitoring point was selected, although it is outside the Upper Illinois River System, to take advantage of the dilution provided by the Kankakee River. The primary purpose of this quality goal is the protection of municipal water use downstream and although some degradation of ABS will occur in the stream, it must be classified as a "persistent" organic molecule. Therefore, any breakdown occurring due to natural purification can be regarded as a factor of safety at any point in the lower river used as a source of drinking water. The ABS concentration recommended above is also recommended by the PHS in the Drinking Water Standards of 1962.

Chlorides

It is recommended that the maximum allowable concentration of chlorides be 100 milligrams per liter. The water of both Lake Michigan and the Illinois River System are usually very low in chlorides in their natural state. Even after addition of chlorides from typical waste waters, the concentration is still well below the allowable PHS Drinking Water Standards of 250 mg/l. There are, however, several industrial processes, boiler water as an example, for which a lower concentration

processes, boiler water as an example, for which a lower concentration of chlorides is desirable. Furthermore, the PHS Drinking Water Standards are national in scope and make necessary allowance for the practical difficulties which exist with respect to available source waters in some parts of the country. It is believed that the existence of such difficulties in other areas should not be regarded as sufficient excuse for permitting an induced deterioration of water quality in more fortunate areas.

Total Dissolved Solids

It is recommended that the maximum allowable concentration of total dissolved solids be 500 milligrams per liter in the Upper Illinois River System.

QUALITY CONSIDERATIONS - LOWER ILLINOIS RIVER

The primary uses of the Lower Illinois River System at present, are municipal water supply (Peoria, Illinois), industrial process water, recreational activities, fish and wildlife habitation, cooling water, commercial shipping, waste-water assimilation and transport, and esthetic enjoyment and property right. Due to the extensive human contact with the waters of the Lower Illinois River, the public health aspects of water quality become paramount. Water quality in the Lower Illinois River is influenced, to a large extent, by the condition of the waters as received from the Upper Illinois River System. Therefore, the achievement of satisfactory water quality in the Lower Illinois River is contingent upon accomplishing the water quality goals recommended for the Upper Illinois River.

If the quality goals recommended herein for the upper river are attained, and appropriate measures taken in critical areas downstream, it is believed that satisfactory quality can be maintained in the lower river. Specific goals are not given in this report for the lower river. However, the levels recommended for the Upper Illinois River System should be adhered to and in no case should the quality requirements be less stringent in the lower river than those recommended in this special report.

A P P E N D I X A

REVIEW OF LITERATURE RELATED TO WATER QUALITY CRITERIA

This section of the special report will present discussions and recommendations contained in principal references dealing with each major use of water. The following is a tabulation of the major uses of water.

List of Water Uses

1. Municipal Water Source
2. Industrial Process Water
3. Recreational Water
    a. Swimming and Water Skiing
    b. Boating, Fishing, and Hunting
4. Irrigation
5. Fish and Aquatic Life
6. Wildlife and Livestock Watering
7. Miscellaneous
    a. Hydroelectric Power
    b. Commercial Shipping
    c. Cooling
    d. Waste-Water Assimilation and Transport
    e. Esthetic Enjoyment and Property Right

The order of presentation in the foregoing list is not intended to signify priority, relative importance, or stringency of quality requirements.

Municipal Water Supply

Where water is to be used for drinking and other domestic purposes, the protection of public health assumes paramount importance; and the specifications for this use become the most compelling, though not necessarily the most exacting, quality requirements.

In evaluating water quality criteria for municipal use, two conditions of the water must be considered: a) quality at the source, be it surface or ground water, and b) quality at the tap or point of use, municipal use without treatment is practical in few areas and with some exceptions is rapidly being discarded, albeit reluctantly, in favor of the reasonable use of such waters. The concept that municipal water should always be treated by some process, if only chlorination, has been adopted almost universally.

The physical, chemical and bacterial quality of drinking water will be judged relative to the recently revised U. S. Public Health Service Drinking Water Standards of 1962 (4). These U. S. Public Health Service Standards are officially applied by the Public Health Service only to the water systems supplying interstate carriers and others subject to Federal Quarantine Regulations. They have been endorsed by the American Water Works Association and are used by most state health departments as criteria for all public water supplies. The extent to which they are enforceable by any state depends on the state and local laws. The principal provisions dealing with quantitative limits are summarized in Appendix B to this special report.

Several state and interstate agencies have promulgated standards or criteria for natural waters used as sources of domestic supply. Among these are the New England Interstate Water Pollution Control Commission, the Interstate Commission on the Delaware River, the Interstate Commission on the Potomac River Basin, Ohio River Valley Water Sanitation Commission, Pacific North West River Basins, T.V.A., and the states of Maine, Maryland, New Hampshire, New York, Oregon, South Carolina, West Virginia, Tennessee, and Washington. The following table has been compiled from information gathered by the U. S. Public Health Service in 1953. This table is a composite of the quality requirements of one or more of the aforementioned agencies.

Table 1

Ranges of Limiting Concentration of Coliforms for Source Water

Constituents	Treatment Required: Disinfection Only	Filtration and Disinfection	Special or Auxilliary Treatment and Disinfection
Coliforms MPN/100ml.			
Monthly Average	50-100	240-5,000	10,000 - 20,000
Max.Day, or Sample		Less than 20%	
		Greater than 5,000	
		Less than 5%	
		Greater than 20,000	

For a source of drinking water, a temperature of 50°F is usually satisfactory, temperatures of 60°F or higher are usually objectionable (3). Increased temperatures can stimulate growth of organisms that produce taste and odor in lakes and impoundments (5).

The total solids concentration in water is the sum of the dissolved solids and the suspended solids. Many authorities, including the Public Health Service, recommend the dissolved solids concentration of potable water should not exceed 500 mg/l. The PHS Drinking Water Standards do not set a limiting concentration for suspended solids (in either raw or treated water), but such concentrations are indirectly controlled by the turbidity requirements. Conventional water treatment methods readily remove suspended solids, but have little or no effect upon dissolved solids concentration. Removal of dissolved solids can be achieved by one of several methods, including de-ionization using ion exchange resins, and distillation.

The PHS Drinking Water Standards of 1962 recommend the concentration of alkyl benzene sulfonate (ABS) be limited to 0.5 mg/l in delivered water. The limit of 0.5 mg/l ABS was recommended for drinking water because higher concentrations tend to cause foaming and taste problems and because levels of ABS much above 0.5 mg/l are indicative of questionable levels of other sewage pollution.

A study by Hurwitz (6) indicates that in the Illinois River System natural processes of purification were unable to keep up with new additions of ABS entering the stream between mile 316 (location of West-Southwest Sewage Treatment Plant of the Chicago Metropolitan Sanitary District) and mile 263 (Morris, Illinois). At Morris, the ABS concentration in the Illinois River was 0.89 ppm. From Morris to Peoria

gradual and continuous assimilation and dilution reduced ABS concentration in the Illinois River to 0.52 ppm at Peoria.

Vogel and Harmeson (7) report a range of ABS concentration in the Illinois River, at Peoria, between 0.1 and 1.22 ppm. Further, that ABS concentrations in ground water near the recharge pits follow closely the concentrations found in the Illinois River and that concentrations of ABS greater than 0.5 ppm have been found in the water distribution system on infrequent occasions.

Industrial Process Water

Due to the diversity of quality requirements for the many differerent industrial processes, it is impractical to make broad generalizations and simplifications. A major consideration for industry is that the characteristics of the source remain relatively constant, and that the quality not deteriorate with time, once the necessary treatment facilities have been designed and built.

Recreational Water

Swimming and Water Skiing - Waters used for swimming must conform to three general conditions: (a) they must be esthetically enjoyable, i.e., free from floating and/or suspended substances, objectionable color, and foul odors; (b) they must contain no substances that are toxic upon ingestion or irritating to the skin or delicate membranes of human beings, and (c) they must be reasonably free of pathogenic organisms (8).

Stream standards that have been promulgated by various state and interstate agencies seldom attempt to define the first two conditions quantitatively - rather, they are qualitative and descriptive. Occasionally limits are set on temperature, pH, color, and turbidity inasmuch as these parameters are easily determined.

Bacteriological standards for swimming waters as recommended by several legal authorities are presented in the following table as excerpted from the table prepared by Garber (9).

Table 2

Bacteriological Standards for Bathing Waters

Authority	Standard	Comparative Geometric Mean
California	20 percent of the samples tested can be greater than 10/ml.	2.5/ml.
T.V.A.	Suitable - Geometric Mean 50-500/100 ml.	Suitable .5-5/ml.
	Doubtful - Geometric Mean 500-1,000/100 ml.	Doubtful 5-10/ml.
Illinois	Median coliform MPN less than 700/100 ml.	8.8/ml.
	If enterococci MPN is greater than or equal to 23/100 ml.	greater than or equal to 23/100 ml.
	Median coliform MPN 700-1,000/100 ml.	8.8-12.5/ml.
	If enterococci MPN is less than 23/100 ml.	less than 23/100 ml.
New York City	Suitable - Geometric Mean 1,000-2,400/100 ml.	Suitable 10-24/ml.
	Doubtful - Geometric Mean greater than 2,400/100 ml. with 50 per cent of samples greater than 2,400/100 ml.	
Detroit	Median less than or equal to 500/100 ml. Maximum Sample 2,400/100 ml.	6.3/ml. Maximum sample 2,400/100 ml.
Michigan	Allowable median less than or equal to 2,400/100 ml.	30/ml.

Garber (9) states that most of the legal authorities based their recommendations of the bacteriological standards on the report by the Joint Committee on Bathing Places (10) or on those of the state and regional organizations. Most agencies have no analytical background for the present limits other than the fact that epidemiological experience under the standards has been good.

Cox (11) presented bacteriological standards compiled by the Michigan Stream Pollution Control Commission (12). The table is as follows:

Table 3

Bacteriological Standards for Natural Waters for Swimming

Phelps Index	MPN[1]	Interpretation
10-100	24-240	Indicative of good water; normal for inland lakes and the Great Lakes; free of sewage pollution.
100-500	240-1,200	Normal for inland streams; free of detrimental sewage pollution; might be attributed to land wash.
1,000	2,400	Suspicious; generally indicates mild pollution in natural waters but dangerous in proximity to fresh sewage pollution.
10,000	24,000	Definite evidence of fresh sewage pollution; menace to health.
100,000	240,000	Heavy sewage pollution; definitely dangerous.

1. The Phelps Index reported by Cox have been converted to MPN for comparison purposes. The conversion was made by the approximation 1,000 Phelps Index is equivalent to 2,400 MPN.

Boating, Fishing and Hunting - It is difficult to draw a sharp line dividing waters used for boating, fishing, and hunting from those used for swimming and water-skiing because these uses blend into each other. Waters used for boating should conform to much the same general conditions that are recommended for swimming and water-skiing. The boating waters should be esthetically enjoyable and contain no substances that are irritating to the skin. Where standards of quality for boating have been recommended, they permit a monthly average MPN as high as 5,000 coliforms per 100 milliliters during the recreational season.

Irrigation

Few investigations have been made of the sanitary quality of irrigation water and there are differences of opinion among health authorities as to the hazards involved. In the absence of widely accepted bacterial standards for irrigation, health authorities have

recommended a high degree of treatment for sewage effluent used for irrigation, and have imposed restrictions on the kinds of crops for which such effluent can be used.

The California State Department of Health adopted in 1933 the following rules, in part, regarding the use of sewage effluents for irrigation:

> "Partially treated or disinfected effluents shall not be used to irrigate truck gardens, berries, or low-growing fruit. Nursery stock, cotton and field crops (to be processed after harvesting) may be watered with such partially treated or disinfected effluents provided that no milch cows are pastured on land moist with sewage or have access to ditches carrying such sewage."

These restrictions do not apply to well oxidized and disinfected effluents which meet the bacterial standards as stated by the Department of Health (3).

The bacteriological quality of sewage effluent used for irrigation water recommended by the PHS (13) and adopted by the Missouri River Drainage Basin is as follows:

1) "Treatment should insure a consistent reduction in coliform bacteria of not less than 90 percent when sewage is used for irrigation of forage crops."

2) "Treatment of sewage used for irrigation of human food crops should insure a consistent reduction (a) in suspended solids of not less than 75 percent (b) in five day 20°C BOD of not less than 75 percent and (c) in coliform bacteria of not less than 98 percent, unless discharged into a stream where the volume of dilution water is at least ten times greater than the maximum anticipated daily volume of sewage during periods of low stream flow, in which case a bacterial reduction of 90 percent may be acceptable."

In the State of Utah, a standard of 5,000 coliforms per 100 ml. has been proposed as a limit for general irrigation, by the Division of Sanitary Engineering.

Substances of concern in the quality of natural irrigation waters may be listed under the following three headings: (a) total salts, (b) substances found in low or trace concentration, and (c) specific

cations and anions. The total salt concentration, the main effect of which is osmotic, is usually stated in terms of specific conductance. The substances found generally in low concentration include compounds of boron, silicon, fluorine, sulfur, phosphorus, iron and other elements; nitrate and amonium ions; hydrogen ion concentration; and organic matter. These substances contribute to the total osmotic effect; they are often essential, in limited amounts, for plant growth; and they are often toxic above certain concentrations. The cations, Ca^{++} Mg^{++}, Na^{+}, and K^{+}, and the anions CO_3^{--}, HCO_3^{-}, SO_4^{--}, Cl^{-}, and NO_3^{-}, contribute to the total osmotic effect. Although these ions are essential for plant growth, they can be toxic above certain concentrations; therefore, they are important because of their detrimental effect upon the soil.

The characteristics of water, which have been accepted thus far as sufficient to determine its suitability for irrigation, are (a) the total concentration of salts, (b) Sodium Adsorption Ratio (SAR) which equals $Na\frac{}{2}\left[\frac{2Na\%}{100-Na\%}\right]^{\frac{1}{2}}$. The SAR can be expressed in terms of milliequivalents per liter of sodium and the sodium percentages (14), and (c) boron, chloride, and sulfate concentrations. These factors may all vary more or less independently, so that water adequate in several respects may be rendered unsuitable due to a high concentration of one constituent, e.g. boron. The allowable concentration for several of the constituents including chlorides, solids and probably ABS will be controlled by plant sensitivity.

Fish and Aquatic Life

Available literature references on the effects of various pollutants on fish and other aquatic life far exceeds that pertaining to any other use of water. Not only are the references on fish innumerable; they are also individualistic in their approach to the problem. The conditions under which studies were made by various researchers were seldom standarized. Hence, results of several investigations of the same pollutant may not compare closely.

Perhaps the most variable and most confusing aspect of the many references is the terminology used to describe end effects. Some authors speak of threshold and limiting concentrations, using the word "threshold" to connote the point at which physiological effects begin or the point at which the use is not impaired to any significant degree but slight effects are noticeable; and the "limiting" concentration is one at which water quality is markedly impaired. Several investigators measure "distress" as indicated by frequency of gill action, others by the feeding or the absence thereof, and others by the reflexes of the fish or their response to stimulants. Some refer to "minimum lethal

concentration" or "minimum lethal dose" with or without defining the time of test and whether one or all of the species succumbed.

The term used to express toxicity in recent literature is the median tolerance limit (TLm). The median tolerance limit is the concentration which kills 50 per cent of the test animals in a given period of time. This term is often written TL_m^t, where t denotes the time required for a 50 per cent kill.

The time-concentration relationship is very important in all investigations of tolerances of fish and other aquatic life toward pollutants. Thus, an organism may withstand a ten minute exposure to 200 ppm of a certain substance, followed by a return to unpolluted water, with no deleterious effects; yet the same organism may succumb to repeated ten minute exposures of that concentration or to a continuous exposure to a lower concentration of the same substance. On the other hand, by continuous exposure to gradually increasing concentrations, the organism may build up a tolerance to concentrations that would be toxic to a non-acclimated organism. The effects of long term exposures of fish populations to very low sub-lethal concentrations are not clearly understood.

The relationship between concentration and time of exposure is extremely important when considering the effect of a slug of waste on the aquatic life of a stream. Generally, a slug containing high concentrations would be more deleterious than a steady discharge with adequate mixing which would produce lower concentrations for a longer period of time. In some instances, however, the concentrated slug may be less detrimental than the steady but weaker pollution.

It is impossible to set up rigid quality requirements or limiting concentrations, for broad general application over a wide area, because many variables, including physiological and environmental, can alter the response of fish to specific constituents of water. Tarzwell (15) stated that in most situations numerical criteria when applied over wide areas can be set only for temperature, DO, and pH. He indicated the DO should not be below 5 ppm for more than eight hours in any 24 hour period, with a minimum of 3 ppm; a maximum allowable temperature of 93°F and a pH between 6.5 to 8.5, with an extreme range between 5.0 to 9.5.

There are myriad conditions, chemical, physical as well as bacterial, that are significant to water quality as it applies to fish and wildlife. Extraneous substances, including inorganic and organic chemicals, municipal and industrial wastes, silt, and also living or dead organisms introduced into a water may be damaging to fish through their effects on water quality. The mechanisms of these detrimental

effects may be due to the direct toxic action upon fish, or indirectly through their effects on the aquatic vegetation, fish food organisms, and spawning facilities which are necessary to support fish life.

Wildlife and Livestock Watering

Very little definite information concerning the quality of water for livestock and poultry use was found in the literature. It has been assumed that water safe for human consumption may be used safely by stock; indeed it has been recommended that for highest productivity to be realized stock should have such water. On the other hand it appears that stock can tolerate higher salinities than men, and it is conceivable also that they differ in their tolerance of specific substances.

The critical values for animal metabolism are the total quantities ingested daily, therefore, the permissible concentrations of such substances in water will depend, to some extent, upon the daily water consumption of the animals. Among the factors which cause the daily water requirements of animals to vary are the temperature and humidity of the atmosphere, the water content of the diet, the degree of exertion by the individual animal with a resultimg loss of water as sweat, and the salinity of the available supply. Under conditions of drought and severe exercise man has been known to consume as much as one gallon per day or more; cattle, 10-16 gallons; horses, 8-10 gallons; sheep and goats, 3-4 gallons; and hogs, 3-5 gallons. The requirements will be much less when favorable climatic conditions are present or no exercise is done (16).

The use of highly mineralized water can cause, among animals as well as among men, physiological disturbances of varying degrees of severity, such as gastro-intestinal symptoms, wasting disease, and death. Generally the first functions of animals to be disturbed by continuous use of water with an unfavorable mineral balance, are lactation and reproduction.

Apart from total salt concentration, some salts are specifically toxic to animals, even in low concentration, and their presence may render the water dangerous for use. Among the most dangerous are nitrates, fluorides, and the salts of selenium and molybdenum.

No limiting concentrations of coliform organisms in contaminated water used for stock watering have been found in the literature. However, it is reasonable to assume that bacterial diseases may be transmitted to livestock as well as to men by infected water. Examples of water borne diseases of animals are anthrax, hog cholera, and tuberculosis. The practical significance of water as a vector of animal disease has not yet been established (3).

Miscellaneous

Five separate uses of water will be discussed within this section. These uses are:

a) Hydroelectric Power

b) Commercial Shipping

c) Cooling

d) Waste-Water Assimilation and Transport

e) Esthetic Enjoyment and Property Right

The combining of these diverse uses is thought reasonable due to the similarity of quality requirements.

Hydroelectric Power and Commercial Shipping - Pollutants in water that interfere with its use for hydroelectric power and commercial shipping are:

1. Substances that accelerate corrosion.
2. Debris, silt and other suspended matter that may block channels and intake devices or settle in reservoirs.
3. Organic matter that causes putrescible odors and corrosive hydrogen sulfide gas.
4. Algae, fungi, worms, and other corollary pollutants that clog passageways or cling to vessels.

Limiting and/or threshold concentrations for each of these categories of pollutants are seldom referred to in the literature. Causes of accelerated corrosion include dissolved oxygen, hydrogen ions, free carbon dioxide, high temperatures, and certain types of bacteria. As for silt, debris and other suspended matter, it is desirable to keep all such material out of natural surface waters, but such a goal is attainable, only through the application of sound land management practices. The formation of putrescible odors and hydrogen sulfide can be minimized by maintenance of aerobic conditions (17).

Cooling - There are two general methods for using water for cooling. The water may be circulated in a closed system, gaining heat, and then returned to a cooling tower or spray pond where the heat is dissipated prior to recirculation. The other method is to use the water once as a cooling agent to extract the undesired heat and then return it to the stream.

When the closed system is used for cooling, water is added to the system as needed to replace the evaporation and wind-blown losses which occur in cooling towers and spray ponds. The three phenomena particularly detrimental to such systems are corrosion, deposition of scale, and the growth of microorganisms. The dangers of using a water that may be corrosive to piping and equipment are obvious; on the other hand, the use of water that tends to deposit scale is also damaging to the cooling system. The scale deposition not only inhibits the physical operation of the system by increasing hydraulic friction, but it also decreases thermal efficiency due to the insulating action of the scale deposit. Microorganisms can contribute to corrosion or form slimes which foul cooling tower surfaces and piping. Consideration must be given the preceding water characteristics in determining whether a given water should be used for cooling purposes. It may also be necessary to treat a make-up water to avoid excessive maintenance costs.

The initial temperature of the water assumes major importance, the lower the initial temperature, the more desirable it is as a cooling water. Water used for once-through cooling and then returned can be detrimental to stream quality by increasing the temperature of the receiving stream. Among the constituents of natural water that may be detrimental to its use as cooling water are hardness, solids, dissolved gases, acids, alkalies, oil and other organic compounds, and slime forming organisms.

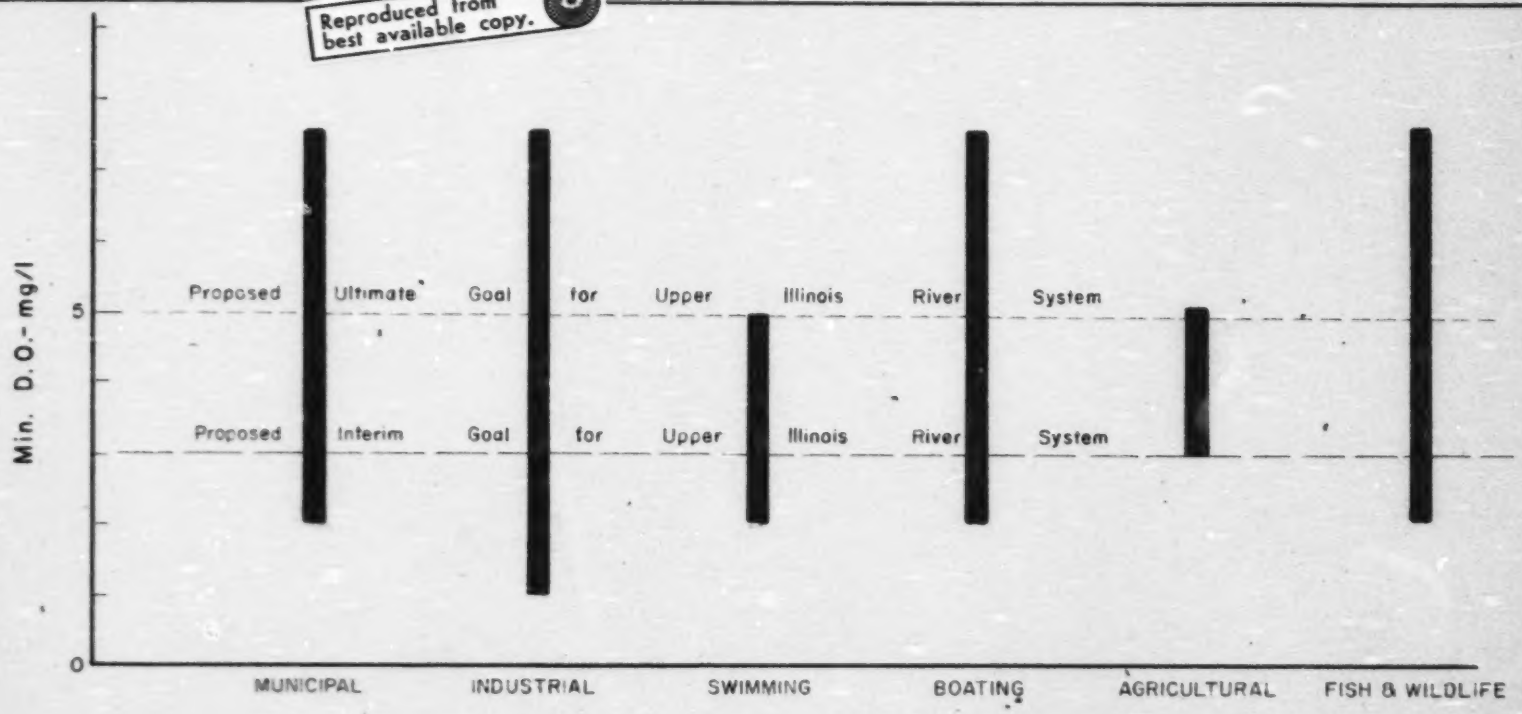
Waste-Water Assimilation and Transport - As a general rule, waters which are used to dilute and assimilate the final effluent from waste treatment plants should have a low temperature, and be rich in dissolved oxygen content. Beyond this, local conditions may impose further restrictions depending upon the nature of the wastes and the use of the receiving waters.

Esthetic Enjoyment and Property Right - It is difficult to make a distinction between waters used only for esthetic enjoyment and not for other purposes. Water quality criteria set forth for the other uses will, as a rule, afford adequate protection from an esthetic enjoyment and property right standpoint.

Graphical Summary

Figures one through four, on the following pages, indicate ranges of values for coliforms, dissolved oxygen, chlorides, and dissolved solids, as found in the literature.

Reproduced from best available copy.



SOURCE-Data compiled by U.S.P.H.S., 1953 (revised 1955)

GREAT LAKES & ILLINOIS RIVER BASINS PROJECT

STREAM QUALITY CRITERIA- RANGE OF VALUES

DISSOLVED OXYGEN CONCENTRATION

DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION V CHICAGO, ILLINOIS

FIGURE 1

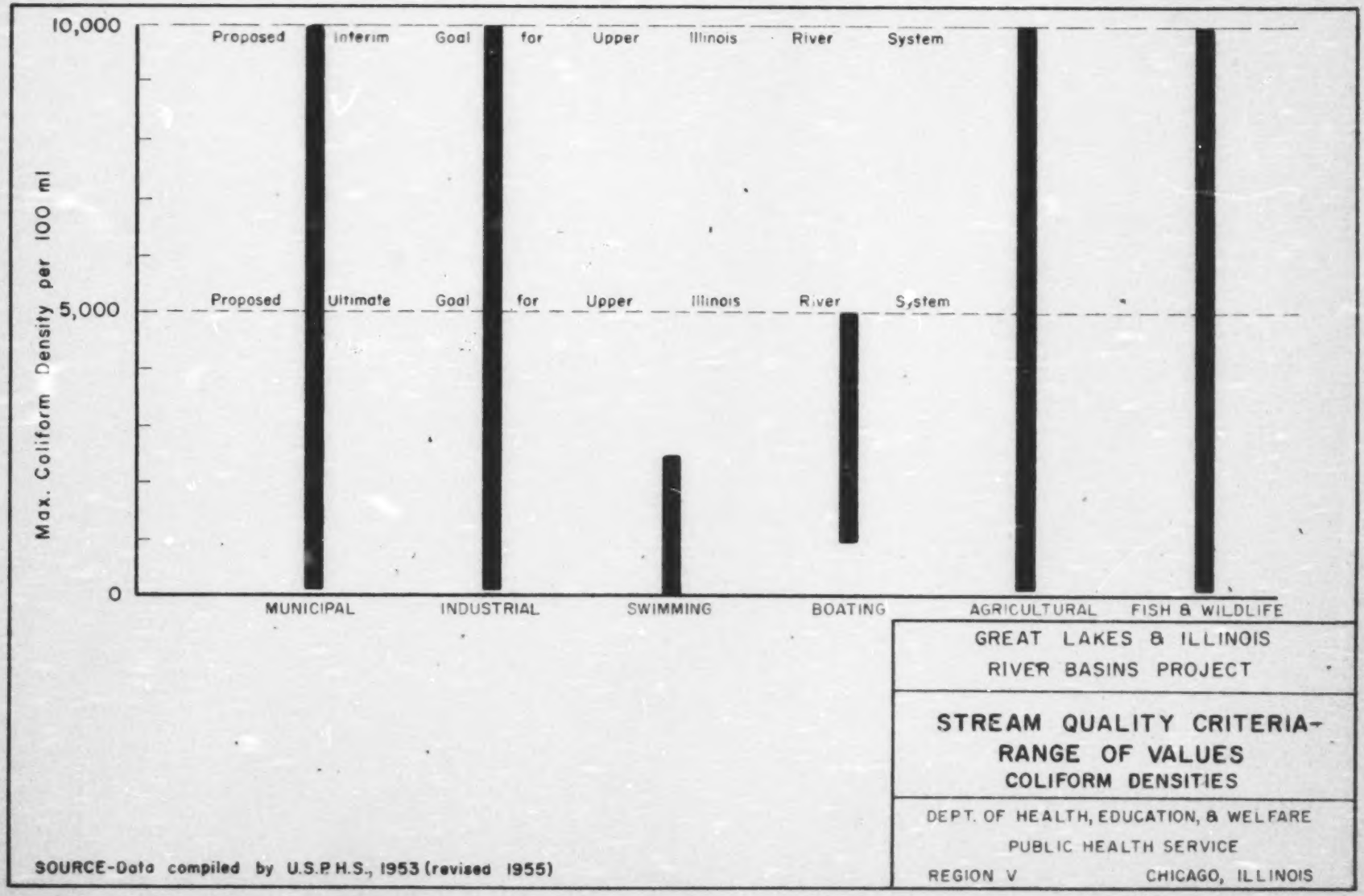
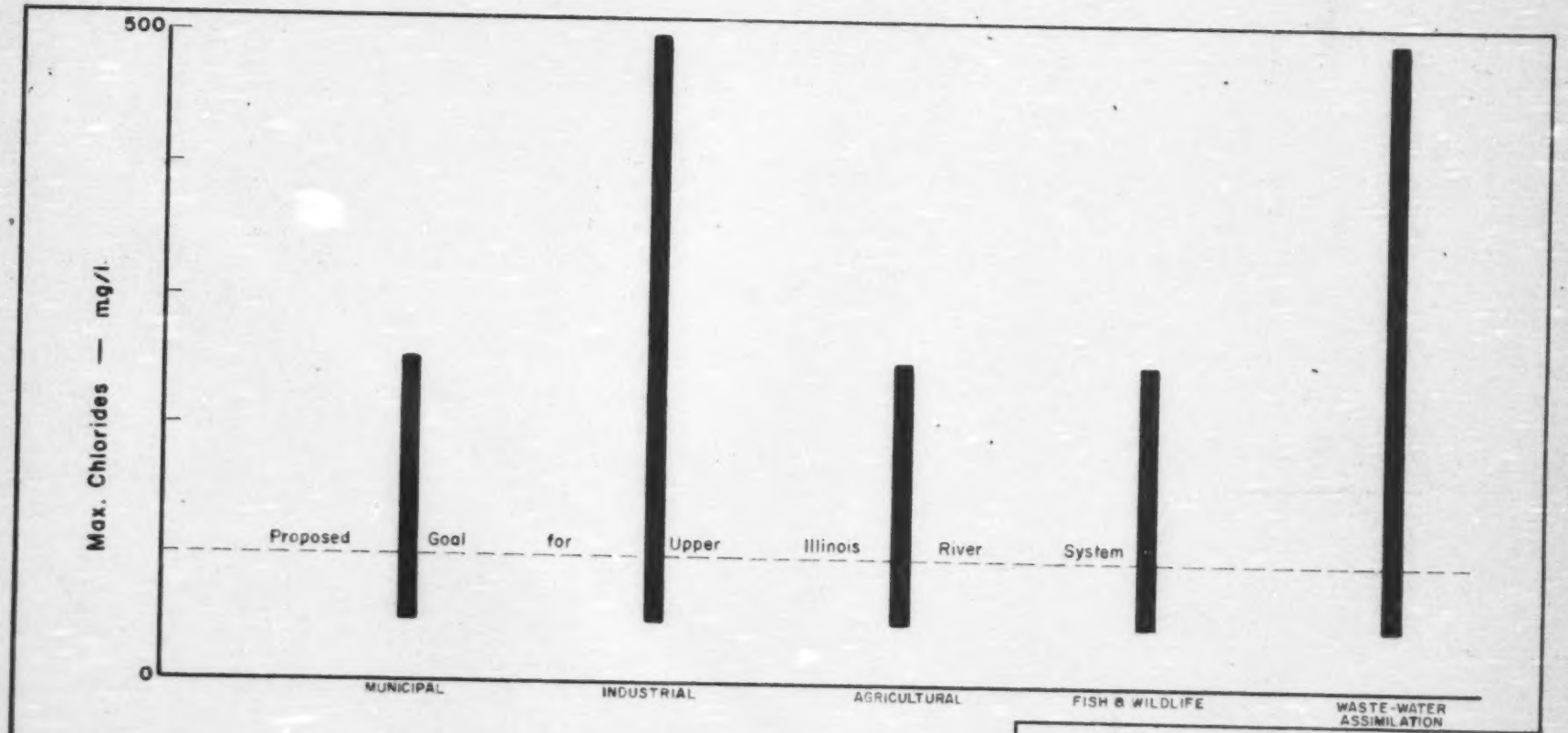

10,000
5,000
0
Max. Coliform Density per 100 ml
Proposed Interim Goal for Upper Illinois River System
Proposed Ultimate Goal for Upper Illinois River System
MUNICIPAL
INDUSTRIAL
SWIMMING
BOATING
AGRICULTURAL
FISH & WILDLIFE
SOURCE-Data compiled by U.S.P.H.S., 1953 (revised 1955)
GREAT LAKES & ILLINOIS RIVER BASINS PROJECT
STREAM QUALITY CRITERIA-
RANGE OF VALUES
COLIFORM DENSITIES
DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION V CHICAGO, ILLINOIS

FIGURE 2



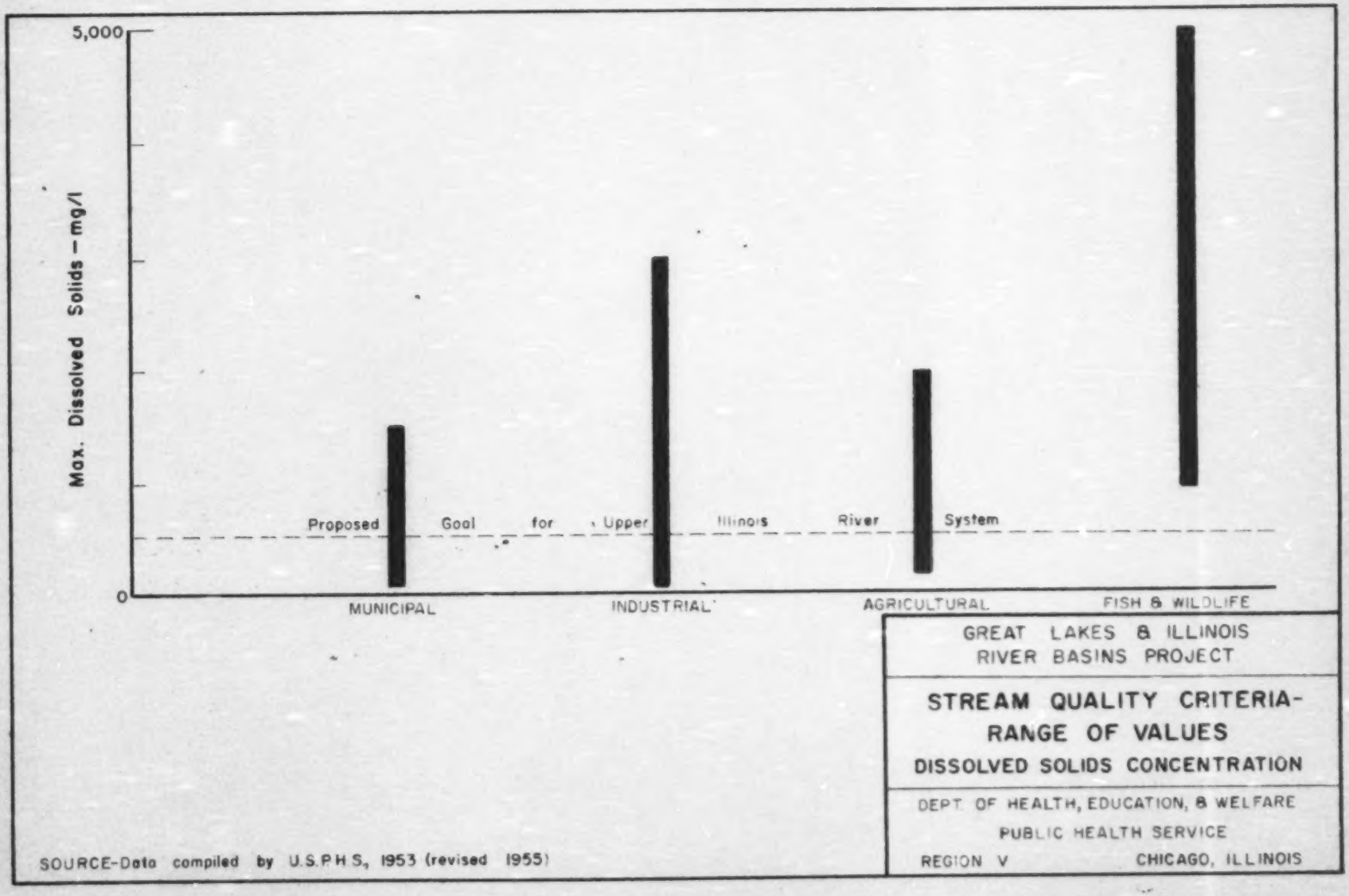
SOURCE-Data compiled by U.S.P.H.S., 1953 (revised 1955)

GREAT LAKES & ILLINOIS RIVER BASINS PROJECT

STREAM QUALITY CRITERIA-RANGE OF VALUES
CHLORIDE CONCENTRATION

DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION V CHICAGO, ILLINOIS

FIGURE 3



GREAT LAKES & ILLINOIS RIVER BASINS PROJECT

STREAM QUALITY CRITERIA-RANGE OF VALUES

DISSOLVED SOLIDS CONCENTRATION

DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION V CHICAGO, ILLINOIS

SOURCE-Data compiled by U.S.P.H.S., 1953 (revised 1955)

FIGURE 4

A P P E N D I X B

PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS - 1962

The Public Health Service Drinking Water Standards were first adopted in 1914. These standards have since received widespread use by various regulatory agencies. Rapid technological development, including atomic energy, and refinement of analytical procedures have necessarily resulted in periodic revision of these standards. To carry out the 1962 revision, the chief sanitary engineer of the PHS appointed an advisory committee composed of representatives of thirteen national professional societies, three federal agencies and one member at large, all directly concerned with the quality of drinking water.

The following is an abstract of the PHS Drinking Water Standards of 1962. The reference for these standards is the 26 Federal Register, 6737, July 27, 1961; Amendments Federal Document 62-2191, March 6, 1962.

Bacterial Quality

The minimum number of samples to be collected from the distribution system and analyzed each month, and the numbers of these samples and portions thereof that may show the presence of coliform organisms are specified. These requirements, in effect, limit the average monthly coliform content to a most probable number (MPN) of one per 100 milliliters.

Physical Quality

"Drinking water should contain no impurity which would cause offense to the sense of sight, taste, or smell. Under general use, the following limits should not be exceeded:"

Turbidity	-	5 units
Color		15 units
Threshold odor number		3

Chemical Quality

The limits for chemical elements and compounds are divided into mandatory requirements and recommended criteria.

TABLE B-1

The mandatory limits are:

Substance	Concentration in mg/l
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Chromium (hexavalent) (Cr^{+6})	0.05
Cyanide (CN)	0.2
Fluoride (F)	See Table B-2
Lead (Pb)	0.05
Selenium (Se)	0.01
Silver (Ag)	0.05

TABLE B-2

Annual Avg. of Max. Daily Air Temperatures[a] (°F)	Recommended Control Limits (Fluoride Concentration mg/l)		
	Lower	Optimum	Upper
50.0-53.7	0.9	1.2	1.7
53.8-58.3	0.8	1.1	1.5
58.4-63.8	0.8	1.0	1.3
63.9-70.6	0.7	0.9	1.2
70.7-79.2	0.7	0.8	1.0
79.3-90.5	0.6	0.7	0.8

(a) Based on temperature data obtained for a minimum of 5 years.

TABLE B-3

The non-mandatory, but recommended, limits are:

Substance	Concentration in mg/l
Alkyl Benzene Sulfonate (ABS)	0.5
Arsenic (As)	0.01
Chloride (Cl)	250
Copper (Cu)	1.0
Carbon Chloroform Extract (CCE)	0.2
Cyanide (CN)	0.01
Fluoride (F)	See Table B-2
Iron (Fe)	0.03

TABLE B-3

Continued

Substance	Concentration in mg/l
Manganese (Mn)	0.05
Nitrate[a] (NO_3)	45
Phenols	0.001
Sulfate (SO_4)	250
Total Dissolved Solids	500
Zinc (Zn)	5

(a) In areas in which the nitrate content of water is known to be in excess of the listed concentration, the public should be warned of the potential dangers of using the water for infant feeding.

Radioactivity

"The effects of human radiation exposure are viewed as harmful and any unnecessary exposure to ionizing radiation should be avoided. Approval of water supplies containing radioactive materials shall be based upon the judgment that the radioactivity intake from such water supplies when added to that from all other sources is not likely to result in an intake greater than the radiation protection guidance[1] recommended by the Federal Radiation Council and approved by the President. Water supplies shall be approved without further consideration of other sources of radioactivity intake of Radium-226 and Strontium-90 when the water contains these substances in amounts not exceeding 3 and 10 micromicrocuries per liter, respectively. When these concentrations are exceeded, a water supply shall be approved by the certifying authority if surveillance of total intakes of radioactivity from all sources indicates that such intakes are within the limits recommended by the Federal Radiation Council for control action.

"In the known absence[2] of Strontium-90 and alpha emitters, the water supply is acceptable when the gross beta concentrations do not exceed 1000 micromicrocuries per liter. Gross beta concentrations in excess of 1000 micromicrocuries per liter shall be grounds for rejection of supply except when more complete analyses indicate that concentrations of nuclides are not likely to cause exposures greater than the Radiation Protection Guides as approved by the President on recommendation of the Federal Radiation Council.

"[1]The Federal Radiation Council, in its memorandum for the President, September 13, 1961, recommended that 'Routine control of useful applications of radiation and atomic energy should be such that expected average exposures of suitable samples of an exposed population group will not exceed the upper value of Range II (20 micromicrocuries per day of Radium-226 and 200 micromicrocuries per day of Strontium-90).'

"[2]Absence is taken here to mean a negligible small fraction of the above specific limits, where the limit for unidentified alpha emitters is taken as the listed limit for Radium-226."

A P P E N D I X C

OBJECTIVES FOR BOUNDARY WATERS QUALITY CONTROL

INTERNATIONAL JOINT COMMISSION UNITED STATES AND CANADA

"In order to permit a more accurate evaluation of the nature and extent of pollution, its effects and the remedial measures necessary, the Commission, in the course of the investigation, adopted the following statement of objectives for boundary waters quality control which was developed by the technical advisers:

"The term "boundary waters" as herein used shall include the waters defined in the references to the International Joint Commission dated April 1, 1946, October 2 and 3, 1946, and April 2, 1948 and are as follows:

St. Clair River, Lake St. Clair, the Detroit River, St. Marys River from Lake Superior to Lake Huron, and Niagara River from Lake Erie to Lake Ontario.

These objectives are for the boundary waters in general, and it is anticipated that in certain specific instances, influenced by local conditions, more stringent requirements may be found necessary.

General Objectives

All wastes, including sanitary sewage, storm water, and industrial effluents, shall be in such condition when discharged into any stream that they will not create conditions in the boundary waters which will adversely affect the use of those waters for the following purposes: source of domestic water supply or industrial water supply, navigation, fish and wildlife, bathing, recreation, agriculture and other riparian activities.

In general, adverse conditions are caused by:

(A) Excessive bacterial, physical or chemical contamination.

(B) Unnatural deposits in the stream, interfering with navigation, fish and wildlife, bathing, recreation, or destruction of aesthetic values.

(C) Toxic substances and materials imparting objectionable tastes and odors to waters used for domestic or industrial purposes.

(D) Floating materials, including oils, grease, garbage, sewage solids, or other refuse.

Specific Objectives

In more specific terms adequate controls of pollution will necessitate the following objectives for:

(A) Sanitary Sewage, Storm Water, and Wastes from Water Craft

Sufficient treatment for adequate removal or reduction of solids, bacteria and chemical constituents which may interfere unreasonably with the use of these waters for purposes aforementioned. Adequate protection for these waters, except in certain specific instances influenced by local conditions, should be provided if the coliform M.P.N. median value does not exceed 2,400 per 100 c.c. at any point in the waters following initial dilution.

(B) Industrial Wastes

(1) CHEMICAL WASTES-PHENOLIC TYPE

Industrial waste effluents from phenolic hydro-carbon and other chemical plants will cause objectionable tastes or odors in drinking or industrial water supplies and may taint the flesh of fish.

Adequate protection should be provided for these waters if the concentration of phenol or phenol equivalents does not exceed an average of 2 p.p.b. and a maximum of 5 p.p.b. at any point in these waters following initial dilution. This quality in the receiving waters will probably be attained if plant effluents are limited to 20 p.p.b. of phenol or phenol equivalents.

Some of the industries producing phenolic wastes are: coke, synthetic resin, oil refining, petroleum cracking, tar, road oil, creosoting, wood distillation, and dye manufacturing plants.

(2) CHEMICAL WASTES-OTHER THAN PHENOLIC

Adequate protection should be provided if:

(a) The pH of these waters following initial dilution is not less than 6.7 nor more than 8.5. This quality in the receiving waters will probably be attained if plant effluents are adjusted to a pH value within the range of 5.5 and 10.6.

(b) The iron content of these waters following initial dilution does not exceed 0.3 p.p.m. This quality in the receiving waters will probably be attained if plant effluents are limited to 17 p.p.m. of iron in terms of Fe.

(c) The odor-producing substances in the effluent are reduced to a point that following initial dilution with these waters the mixture does not have a threshold odor number in excess of 8 due to such added material.

(d) Unnatural color and turbidity of the wastes are reduced to a point that these waters will not be offensive in appearance or otherwise unattractive for the afore-mentioned purposes.

(e) Oils and floating solids are reduced to a point such that they will not create fire hazards, coat hulls of water craft, injure fish or wildlife or their habitat, or will adversely affect public or private recreational development or other legitimate shore line developments or uses. Protection should be provided for these waters if plant effluents or storm water discharges from premises do not contain oils, as determined by extraction, in excess of 15 p.p.m., or sufficient amount to create more than a faint iridescence. Some of the industries producing chemical wastes other than phenolic are: oil wells and petroleum refineries, gasoline filling stations and bulk stations, styrene copolymer, synthetic pharmaceutical, synthetic fibre, iron and steel, alkali chemical, rubber fabricating, dye manufacturing, and acid manufacturing plants.

(3) HIGHLY TOXIC WASTES

Adequate protection should be provided for these waters if substances highly toxic to human, fish, aquatic, or wildlife are eliminated or reduced to safe limits.

Some of the industries producing highly toxic wastes are: metal plating and finishing plants discharging cyanides, chromium or other toxic wastes; chemical or pharmaceutical plants and coke ovens. Wastes containing toxic concentrations of free halogens are included in this category.

(4) DEOXYGENATING WASTES

Adequate protection of these waters should result if sufficient treatment is provided for the substantial removal of solids, bacteria, chemical constituents and other substances capable of reducing the dissolved oxygen content of these waters unreasonably. Some of the industries producing these wastes are: tanneries, glue and gelatin plants, alcohol, including breweries and distilleries, wool scouring, pulp and paper, food processing plants such as meat packing and dairy plants, corn products, beet sugar, fish processing and dehydration plants."

NOTE: The methods of determination of the chemical constituents referred to in the preceding Objectives are as given in "Analytical Methods for Boundary Waters Quality Control," as prepared by the Board of Technical Advisers. Bacterial determinations are to include the presumptive and confirmed tests for the coliform group of bacteria as given in "Standard Methods for the Examination of Water and Sewage," American Public Health Association, New York.

This appendix is reproduced in its entirety from pages 18 and 19 of the International Joint Commission United States and Canada, Report on Pollution of Boundary Waters (1951).

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